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Review

Sustainability Assessment Methodologies: Implications and Challenges for SIDS

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Abstract: Over the past years, an increasing number of initiatives was considered to address emerging global sustainability issues. Sustainability assessment tools were the most commonly applied methodologies towards measuring sustainability performance. There are a number of assessment tools and techniques for sustainable development. This article aims at identifying the various sustainability assessment tools at country level taking into consideration the integration of environmental, economic, and social dimensions. The target of this paper is to compare the various sustainability measurement techniques and their characteristics using evaluation criteria. The outcome of this analysis is used to direct and clarify researchers and practitioners on sustainability assessment at country level, more specifically in developing countries. The focus of the paper rests on the Brundtland Report definition of sustainable development. The work was carried out using a bibliometric analysis approach based on Web of Science platform from the period 2000 to 2020. There was tremendous works which were conducted on sustainability assessment during the last two decades. The comparative analyses show the research gap among the various tools with respect to the criteria they satisfied. The research discussion suggests that a sustainability assessment framework for Small Island Developing States (SIDS) is identified as a future research direction.

Keywords: sustainability assessment; country level assessment; small island developing states; triple bottom line approach

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1. Introduction

In recent years, the earth system has experienced drastic changes. The consequences of the ecosystem change have influenced human wellbeing including health, social relationship, security, and other components. Human activities are exerting pressure on the ecosystem and this has affected the life-support system for humans [1]. This has had adverse effects such as environmental degradation, economic crisis, and social instability. Despite several global actions were undertaken in order to minimize the risks—the problems are still prevailing. The idea of preserving the natural resources has become a matter of great concern. To respond to this challenge, sustainable development has emerged during the past decades. It has integrated the global political world in the 1970s in the United Nations Conference on Human Development. It has predominantly become one of the most emerging fields with high-level priority for many countries [2].

Sustainable development has been defined in many ways but the one quoted in the Brundtland Commission report has posed a real challenge in business practices and has also helped practitioners to understand the ecosystem, economic situations, and social effects of projects [3]. Sustainable development is defined as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [4]. It has evolved to shape global development policies and agendas. Since the term was coined, it was extensively used and has undergone different interpretations but the most cited definition was the one from the Brundtland commission report. However, progress towards sustainable development is vital in order to preserve a balance between

human activities and the ecosystem. Despite efforts made by scientists in certain areas, there are still some key challenging issues in sustaining a country. The reason behind is that sustainable development is not easy to define as no one can tell exactly what is sustainable or not [5]. Sustainable development has helped scientists by gradually changing the way in which development is being applied in various areas while preserving the ecosystem and the natural resources. The development was influenced by the assumption made by researchers through various definition of sustainable development making it appear differently in various sustainability fields but finally led to transforming sustainable development to its real sense. However, sustainable projects have become a priority objective internationally. The main goal is to transform unsustainable present into a sustainable future. Sustainability aims at maintaining the natural resources from unfair and inadequate use in the short and long term [6]. However, the big challenge remains maintaining sustainability at any levels. The complexity increases when sustainable development is being considered in developing countries more specifically in small island states. This is due to ongoing global changes such as overexploitation of natural resources, sea-level rise, carbon emissions, and waste generation. For example, population growth can cause irreversible changes in production and consumption in the long run. Furthermore, food security can be affected by water supply and hence increases carbon emissions. It is quite difficult to see this inter-connectedness.

Sustainable development has emerged as a concept in Small Island Developing States (SIDS) while considering the economic growth, environmental aspect, and social development in order to satisfy human beings basic needs without compromising the life of the future generations. The main concern is how to remain sustainable with constant changes in technology, economic instability, and environmental degradation. Despite its complexity and vagueness, many tools have been proposed for measuring sustainability performance but very few studies have shown the application of comprehensive techniques for SIDS [7]. These small island states face common challenges due to their size, rapid population growth, small domestic markets, exposure to natural disasters, and geographical localization. Studies have been focused on various sustainability spheres individually and when they are treated separately, they are more enlightening [8]. The tools and techniques which focus mainly on specific sustainability dimensions have caused a real confusion in the sustainability field itself [9]. Many of the proposed sustainability assessment frameworks were often criticized [10]. Most of these tools have not yet been fully established [11]. They do not match the complexity of the problem as very few techniques fully considered the integrated sustainability spheres [12]. Sustainability is an integrated concept and a more convenient approach is required. There are very few techniques fully focused on sustainability as a whole [13]. The triple bottom line approach can address this issue from a broader perspective. Its concept has been widely accepted in the sustainability fields [14].

Changes occurring in the world today are affecting the SIDS environmental conditions, the economic situations, and societal issues [15]. They are vulnerable to climate change which is a major social issue impacting on humans [16]. They are also affected due to their small scale, exposure to natural disasters, remoteness, sea level rise, limited resources, and multiple drivers and pressures [17]. In most SIDS, many people live in a coastal region. Due to their ecosystem fragility and economical vulnerability, they are prone to face many challenges while implementing sustainable development [18]. Compared to developed countries, they are most exposed to storms, floods, and other threats such as emissions which they found difficult to reduce and move to renewable energy. Energy is a high priority for most SIDS as it encompasses the social, economic, and environmental challenges [19]. These small island states are highly dependent on imported fuels for transport and electricity production and also on cleaner energy production particularly wind and solar resources which is a financially sustainable option [20].

Sustainability assessment was always a subject matter for various countries and SIDS. Various traditional mathematical based modelling techniques such as system dynamics and Multi Criteria Decision Analysis were used for sustainability assessment. Since these

techniques cannot deal with uncertainties and complexities, they are found ineffective in assessing sustainability performance. Sustainability performance assessment is limited in small island states as they are more vulnerable compared to developed countries in the sense that the ecosystem is being affected by human activities [15]. The work aims to identify various existing sustainability assessment tools for comparison. Our study also examines the different characteristics of these assessment tools. However, the research can contribute to the development of a new tool based on the strengths and weaknesses of existing tools. For the purpose of this study, the Brundtland definition of sustainable development was adopted.

2. Materials and Methods

This paper provides a guidance of an extensive research carried out in order to determine what kind of methodological approaches are appropriate in identifying sustainability measurement techniques. It is important to design a plan for the literature search process based on discussion with experts. An exploratory literature review was also undertaken in order to provide a broad approach to the subject area and how to proceed with the review process. The identification and selection of assessment tools are also discussed.

2.1. Bibliometric Data Analysis

The flowchart in Figure 1 describes the processes that were used to filter and screen the different articles.

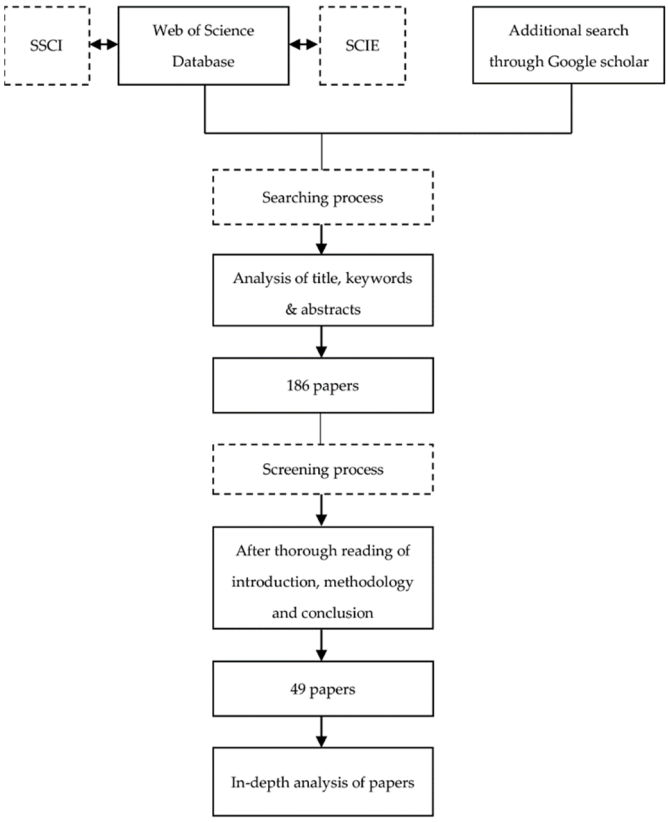

Figure 1. Literature search flow diagram.

The Web of Science (WOS) was used as a multidisciplinary bibliographic data source to extract bibliometric information. The WOS as you know is a structured database which contains a lot of top publications research papers. Data were retrieved using a set of keywords based on the title of this paper. The papers were identified from a collection of database, namely, Social Science Citation Index (SSCI) and Science Citation Index Expanded (SCIE) within the WOS database. A combination of keywords was employed to

retrieve the papers related to the sustainability assessment tools. The keywords used are as follows "sustainability assessment tools" OR "sustainability assessment methodologies" OR "sustainability measurement techniques". The keywords were based on the texts that matched those texts in the metadata in order to identify the various sustainability assessment techniques. Other non-specific keywords were also used while ensuring the keywords were present in the title and the abstract. The most referenced research papers regarding sustainability assessment tools were also identified. We limited ourselves to integrated assessment tools at country level.

The search was conducted in January 2021 and a total of 186 papers were collected. There was no start date in the search query in order to retrieve all potential research papers focusing on sustainability performance measurement tools. Additional verification was done by extending the search strings on Google scholar to ensure that some key journals related to sustainability assessment tools were included. However, the number of research papers on sustainability assessment techniques has been growing. We also identified sustainability performance measurement in different context but also observed that sustainability assessment was lacking in Small Island Developing States. The validation process was based on 49 most cited documents in sustainability assessment which were reviewed to ensure that they were fully related to sustainability tools based on the integrated spheres. This has helped in eliminating false-positive results by ignoring articles focusing on sustainability performance measurement as a whole or other irrelevant documents which measure sustainability spheres individually.

2.2. Evaluation of Sustainability Assessment Tools

A total of 28 tools were obtained from various papers related to sustainability assessment but only 7 tools were selected for analysis. The selected tools were based on the structure of the triple bottom line as it combined the environmental, economic, and social dimensions. This study was carried out using a three-stage procedure to evaluate the different sustainability assessment tools.

The first stage was based on a four-point scale and the three sustainability dimensions. The categorization of assessment tools was done on a four-point scale basis which was presented into product-based, project-based, sector-based, and country-based assessment. The purpose of categorizing the assessment tools helps to determine in which area sustainability assessment was conducted and the numbers of sustainability dimensions that were addressed.

The second stage includes selecting tools based on country level assessment that fulfilled the three sustainability dimensions. Further analysis was done on these tools using the scale and dimensions and the factors they considered for each dimension. The number of indicators under each factor were also categorized. It is important to identify the indicator sets for each tool as this helps to know the different aspects that were considered at country level. This also serves as a monitoring technique to monitor progress on a national level perspective more precisely SIDS.

The third stage includes further analysis of the selected tools based on criteria that are also applicable for SIDS. However, the existing literature provides very limited literature on such criteria [12,21]. For the purpose of this study, the pre-defined criteria in the studies of [12,21] were considered accordingly. This is necessary for the development or application of a sustainability assessment tool for SIDS. These criteria are as follows:

(1) Robustness—The ability of a model to provide accurate results and remain effective even if there is a change in the input variables;
(2) General applicability—The tool is tailored for a specific purpose and its application in other fields is limited;
(3) Rapid Assessment—Due to its ambiguity, sustainability assessment can be very time-consuming. Therefore, the speed within which data can be accessed for measurement represents a high degree factor. In case for small data measurement, the data collection

process is simplified thus reducing the assessment time. The time period to conduct assessment should be reasonable. The tool must be easy to use and manipulate;

(4) Comprehensive view of sustainability—The tool should be efficient, the analysis should be precise, and should include an integrated evaluation of the three sustainability spheres.

3. Research Findings

The selected articles that conformed to criteria for this research on sustainability assessment tools are presented in this section. The number of existing tools are also tabulated according to the scale assessment is conducted and the sustainability dimensions they consider. The selection of existing techniques and the number of indicators that each selected tool has are also discussed. An overview of each selected assessment techniques is given and finally an in-depth analysis is done based on criteria applicable for SIDS.

3.1. Literature Analytics and Publishing Trends

The number of papers that conformed to sustainability assessment tools varied from 2000 to 2020 as shown in Figure 2 and a total of 186 publications were selected from this phase. The number of published articles from 2000 to 2010 was 23% of the total selected papers. From 2011, the number of published papers has increased to 142 which represents 3.4 times as compared to 2000. The trend also indicates that there was an increased attention on sustainability assessment techniques and methodological approach during the last ten years. During the past 20 years, many studies on sustainability assessment tools have gained momentum and this gradual increase has been proven by the greatest volume of articles published in 2020. While increased attention is focused on sustainability assessment techniques at country level where great consideration is paid on the integration of the three sustainability spheres, it is clear that sustainability performance measurement can be also adopted to global sustainability issues. The publication trend from Figure 2 demonstrates the evolution in the number of articles with the highest number recorder as from 2016.

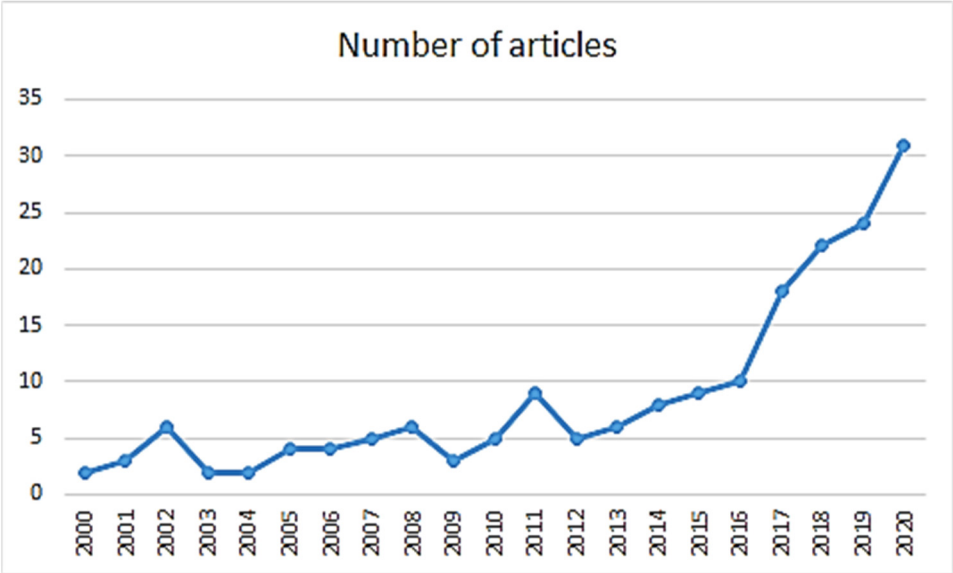

Figure 2. Annual trend analysis of research papers.

There were 186 journals relevant to sustainability assessment tools. The 49 selected papers were published in 12 of the most cited journals. Figure 3 shows the top journals related to assessment tools and techniques with Sustainability (26%), representing 13 articles, followed by Ecological economics (16%), Ecological indicators (14%), Journal of Cleaner Production (10%), and others. The published papers were concentrated mainly

in countries like Netherlands, USA, UK, Switzerland, and Japan. These countries are the largest distributers of articles published in this research area.

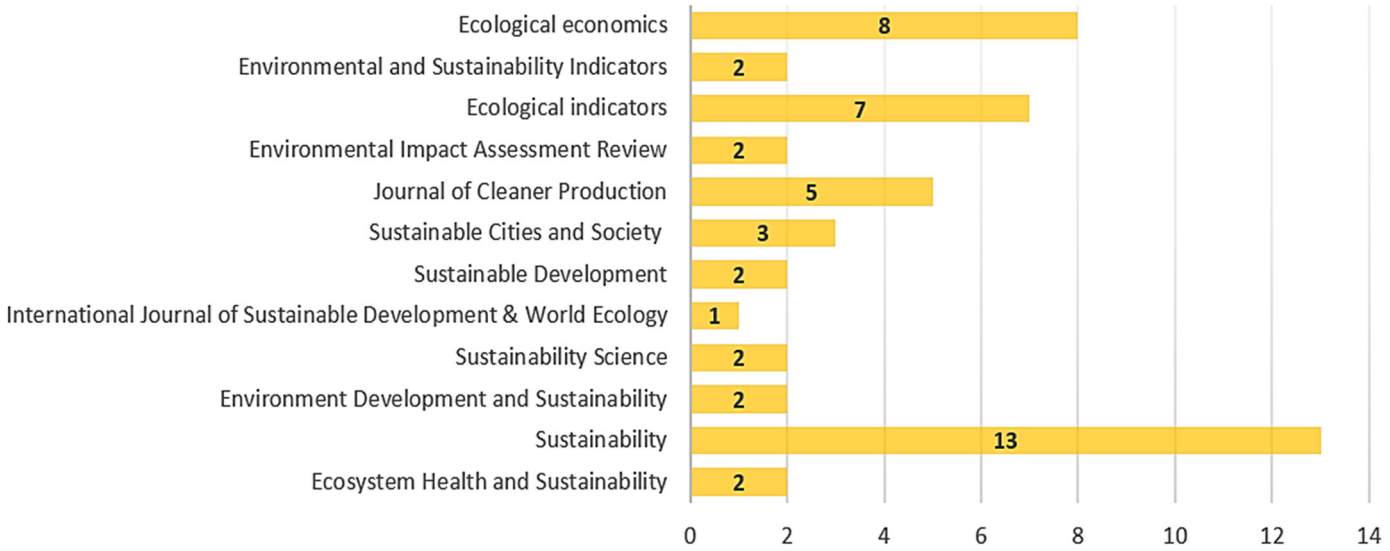

Figure 3. Main journals on Sustainability assessment tools.

3.2. Overview of Sustainability Assessment Tools

Based on the scales and dimensions, the 28 tools are ranked according to their applicability at different scales and the sustainability dimensions that are taken into consideration. Then the state of environmental, economic, and social aspects at country level is presented with respect to the various factors and number of indicators each sustainability dimension has, as seen in Table 1.

Table 1. Sustainability assessment tools.

	Scale				Dimension		
	Product	**Project**	**Sector**	**Country**	**Environmental**	**Economic**	**Social**
Life Cycle Assessment (LCA) [22]	√				√		
Dow Jones Sustainability Index (DJSI) [23]			√		√	√	√
Environmental Sustainability Index (ESI) [24]				√	√		
Environmental Performance Index (EPI) [25]				√	√		
Ecological Footprint (EF) [26]				√	√		
Sustainable Society Index (SSI) [27]				√	√	√	√
Life Cycle Costing (LCC) [28]	√					√	
Human Development Index (HDI) [29]				√		√	√
Environmental Impact Assessment (EIA) [30]		√			√		
Sustainable National Income (SNI) [31]				√	√	√	
Social Life Cycle Assessment (S-LCA) [32]	√						√
Strategic Environmental Assessment (SEA) [33,34]			√	√	√		
Index of Sustainable Economic Welfare (ISEW) [35]				√		√	
National Sustainable Development Index (NSDI) [36]				√	√	√	√
Composite Sustainable Development Index (I_{CSD}) [37]			√		√	√	√
Full Cost Accounting (FCA) [38]		√				√	

Table 1. *Cont.*

	Scale				Dimension		
	Product	**Project**	**Sector**	**Country**	**Environmental**	**Economic**	**Social**
Integrated Value Model for Sustainable Assessment (MIVES) [39,40]		√	√		√	√	√
Cost–Benefit Analysis (CBA) [41]		√			√	√	√
Genuine Progress Indicator (GPI) [42]				√		√	
Life Cycle Sustainability Assessment (LCSA) [43]	√				√	√	√
System Dynamics (SD) [44–47]	√	√	√	√	√	√	√
Multi Criteria Decision Analysis (MCDA) [48,49]			√	√	√	√	√
Sustainability Assessment Model (SAM) [50,51]		√	√		√	√	√
Barometer of Sustainability (BS) [52]				√	√	√	√
Fuzzy Evaluation for Life Cycle Integrated Sustainability Assessment (FELICITA) [53]	√				√	√	√
Sustainability Assessment by Fuzzy Evaluation (SAFE) [54,55]			√	√	√	√	√
Fuzzy Logic Approach for Sustainability Assessment based on the Integrative Sustainability Triangle (FUZZY-IST) [56,57]		√	√		√	√	√
Adaptive Neuro-Fuzzy Inference System (ANFIS) [58,59]			√	√	√	√	√

There has been considerable debate on improving sustainability performance for social and environmental wellbeing of a country as well as the financial wellbeing [60]. A sustainable country can be defined by integrating the three pillars. Environmental development is the demand that human activity must respect in order to satisfy its needs without harming the life support systems of the planet on a regional, national, and international level [61]. The social dimension refers to the development of people and cultures as well as proper healthcare, education, and stability of a country [62]. Economic dimension refers to how the production level meets the needs of the number of consumers presently while considering the next generation [63]. Many assessment tools were developed on the specificities of the area under study and others were focused partly or mainly on individual dimension rather than considering sustainability as a whole. Sustainability assessment at country level shows an indication of the overall sustainable development conditions [64]. This is why it is important to consider the three sustainability dimensions as they function properly as an integrated system at this level.

There are many assessment tools and techniques which were developed to measure sustainability performance at various level [65] but the complexities arise when it concerns which tool is appropriate for particular areas to be investigated such as small island states. Due to its small size and vulnerabilities, SIDS need a model with completeness. As shown in Table 1, various tools and techniques are analyzed to address sustainability issues of small island states. There are major constraints SIDS are actually facing such as the development of indicators, unavailability of data and most importantly lack of resources. In order to address these limitations, a comprehensive model is needed. It can be noted that there are very few initiatives that address the three pillars at country level. Tools are selected based on integration of the sustainability spheres and country level analysis. Product-based, project-based and sector-based assessment tools are not considered in this study. Table 2 summarizes the tools which were identified for analysis.

Table 2. Sustainability tools assessment criteria.

Tools	Dimension	Factor	Number of Assessment Criteria
Sustainable Society Index (SSI) [27]	Human Wellbeing	– Basic Needs – Personal Development & health – Well-balanced society	21 basic indicators
	Environmental Wellbeing	– Natural resources – Climate & energy	
	Economic Wellbeing	– Transition – Economy	
National Sustainable Development Index (NSDI) [36]	Economic	– Economic growth – Income level – Economic structure	12 suitable indicators related to each factor
	Resource and environmental	– Climate – Air quality – Forest – Arable land – Energy	
	Social	– Education – Health – Drinking water – Sanitation facilities	
System Dynamics (SD) [47]	Human needs	– Demand for Economic support – Supply human needs	Not composed of fixed indicators. Adapted to changes in the system.
	Economic	– Economic capital – Expenditures and depreciation – Economic growth – Economic capital – Demand for economic utilization	
	Environment	– Renewable resources – Non Renewable resources – Waste generation – Ecological biodiversity – Ecosystem carrying capacity	
	Life services structure	– Available life services – Supply life services – Population growth	
Adaptive Neuro-fuzzy inference system (ANFIS) [59]	Ecological	– Air quality – Land integrity – Water quality – Biodiversity	On SAFE basis (75 optional general indicators)
	Human	– Political aspects – Economic welfare – Health – Education	
Multi Criteria Decision Analysis (MCDA) [49]	Human Wellbeing	– Basic Needs – Personal Development & health – Well-balanced society	On SSI basis (52 optional general indicators depending on available data)
	Environmental Wellbeing	– Natural resources – Climate & energy	
	Economic Wellbeing	– Transition – Economy	

Table 2. *Cont.*

Tools	Dimension	Factor	Number of Assessment Criteria
Barometer of Sustainability (BS) [66]	Human	– Health & population – Wealth – Knowledge & culture – Equity – Community	Not composed of fixed indicators. The methodology is flexible.
	Ecosystem	– Land – Air – Water – Species & population – Resource use	
Sustainability Assessment by Fuzzy Evaluation (SAFE) [67]	Ecological	– Air quality – Land integrity – Water quality – Biodiversity	69 basic indicators related to each factor
	Human	– Political aspects – Economic welfare – Health – Education	

The selected tools for sustainability performance measurement at country level are based on the environmental, economic, and social issues. The table shows the different factors from the sustainability dimensions which were considered and the number of indicators used from a national level perspective. These tools allow country assessments that help to determine the pressure human is exerting on the ecosystem. Most of the assessment tools are based on an integrative approach that make them very efficient in dealing with complex sustainability issues. Some tools like System Dynamics, Multi Criteria Decision Analysis and Adaptive Neuro-fuzzy Inference System are not necessarily applied directly to measure sustainability performance but provide some other benefits to various fields as well.

In order to perform sustainability performance measurement, the number of indicators used in each model is the most important factor that contributes to decision-making alternatives. They are analyzed based on the various factors constructed from a wide range of sustainability indicators in order to address the most important sustainability issues. Sustainability assessment is done in accordance with the sustainability development objectives at country level. Indicators are considered to be a crucial point for tracking the quality of a system [68]. It also provides comprehensive information about the system in order to guide decisions at all levels within a country [69]. The number of indicators should be small as possible and cover all aspects that are relevant to the system. However, indicators differ in some cases depending on where they are used. The choice of indicators is not the same for local, national, or international level. Most of the indicators identified in the literature were used at national level. For instance, the selection of indicators should reflect the interest of stakeholders and compare the development path.

3.3. Critical Perspective of Sustainability Assessment Tools

Sustainability performance measurement was always a challenge for many countries. There are various tools and techniques which were applied in sustainability fields but very few of them addressed the three spheres in an integrated way. In order to clarify the complexities that exist in this field, various existing methodologies were analyzed. Some of the existing tools consider the economic, environmental and social spheres independently or partly. After analyzing the identified tools, only seven tools were selected because they focused mainly on integrated assessment. Furthermore, the challenges that prevail in SIDS can be addressed by considering integrated sustainability assessment tools. Since

very few research studies were conducted in assessing sustainability performance of small island states, it is important to understand their concept and characteristics as SIDS are still debating on how to implement sustainable development strategies [7] due to serious environmental degradation and unique vulnerabilities. It is important to have appropriate tools that have the capabilities to deal with issues SIDS are actually facing. The selected tools vary in the way that they work and the parameters they consider. Each model has different characteristics which make them an ideal tool to provide an overall assessment of sustainability performance of small islands. Only few models are concerned with integrated sustainability assessment.

3.3.1. Sustainable Society Index (SSI)

The Sustainable Society Foundation in Netherlands developed the Sustainable Society Index (SSI) in 2006 to provide governments an easy tool to measure the sustainability of a society. The SSI is also used to measure the wellbeing of the human–environmental systems of a country and set priorities with respect to sustainability. The framework is based on a protective approach in order to optimize the impact human activities are exerting on the natural system. The aim of the SSI is to draw the pattern along the human, economic, and environmental dimensions. The SSI is widely applicable for ongoing measurement of the coupled human–environmental systems and due to its statistical information, future progress can be compared and appropriate societal measures can be taken promptly. It has 21 indicators which are categorized using seven factors based on the three sustainability dimensions. However, the SSI is one among existing indices which comprises the three wellbeing dimensions, namely, human, environment, and economic. The main priority is the human–environmental dimension and the economic dimension is a mandatory aspect to achieve full sustainability.

3.3.2. National Sustainable Development Index (NSDI)

National Sustainable Development Index (NSDI) is a modified version of the Human Development Index [36]. The tool is basically used to measure sustainable development and identify the major constraints with other existing indices in order to develop proper measures at national level. The NSDI uses the entropy method to calculate the weights in a more objective way. It also composes of a complete sustainability index that HDI and other indices do not consider. The three spheres are also enhanced as compared to existing indices. Indicators are selected from each area but the selection is based on certain criteria where the most suitable and representative ones are taken into consideration. The NSDI is a comprehensive index with 12 important indicators that cater for the environmental, economic, and social dimensions. The NSDI was calculated for 163 countries whose data were available for the 12 indicators. It fully considers the three sustainability spheres which help to conduct sustainability performance measurement at country level in a more comprehensive way. It was found to be a very reliable index for sustainable development.

3.3.3. System Dynamics (SD)

System Dynamics (SD) was originally developed in the 1950s by Forrester [70]. It is a powerful methodology and mathematical modelling technique designed to understand and deal with issues and problems in complicated systems. In the 1950s to 1960s, SD was generally used by corporate managers to understand some problems. SD is mostly used to study the behavior of complex systems. The model uses a standard causal loop approach which comprises of several dynamic simulation sub-systems. The model can analyze the information feedback processes between the components along with stock and flow structures to deal with the problem in a system. By understanding the structure of the system, it is possible to draw the causal loop diagrams. The diagram interprets graphically the relationship between systems and their parts and how they interact with each other.

SD enhances learning in complicated systems which is another main characteristic of SD [71]. It is worth drawing the causal loop diagram in order to gain better understanding

of processes as well as the system's mechanisms and feedback loops. Through learning process, it is possible to change the decision rules and improve the system's behavior and performance. It can also adopt other modelling structures that meet future demands according to user's perception. Many scientists have gone through a profound study of this method [72]. In addition, this model functions in a whole-system mode which makes it a powerful tool to deal with sustainability issues [47]. It was found to be a perfect tool to analyze the complex interaction in sustainable development [73].

However, evaluating the model is one of the most important feature in the process since the user may acquire confidence in the model. It is essential to evaluate the model during the development phase rather than after completion of the model. Evaluation should be conducted during all phases of the simulation as most of the time developers complete the whole model at first then conduct evaluation tests afterwards. Developing such model does not guarantee a high quality tool whose behavior suits reality. The major problem with the causal loop diagrams is that they cannot make the difference between information links and rate-to-level links [74]. After the analysis, it is important to develop the stock and flow diagram as it is highly recommended. The causal loop diagram is useful for novice in system dynamics as a first step, it can give a good systematic analysis of the system under study.

3.3.4. Adaptive Neuro-Fuzzy Inference System (ANFIS)

The Adaptive Neuro-Fuzzy Inference System model were applied in various studies to solve many problems [75]. This model possesses major advantages as it is based on a combination of fuzzy logic and neural networks where it maps the input and output data to give optimal membership functions. The ANFIS was found to produce significant results in non-linear systems [76,77]. The major concern with adaptive network is that its configuration should be like a feedforward style. ANFIS technique is very efficient for sustainability performance evaluation. It has some advantages such as the decision rules are generated automatically without human intervention and also accepts large number of input/output variables. However, due to an increase in the number of variables, the computation time also increases and hence makes the model become restricted for large datasets. In this situation, the membership functions need to be reviewed.

3.3.5. Multi Criteria Decision Analysis (MCDA)

The MCDA is a framework that can support complex decision-making situation with objectives that policy-makers often value different. The term is defined as an "umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups to explore decisions that matter" [78]. Its origin is from operations research [79] and has extensively been used in management [80]. It has been widely used in evaluating sustainability as well [81]. This method is useful as it can help in reducing complexities and deal with a solid base for decision making. Some researchers do not properly define why they have opted for MCDA method instead of another. Before applying the MCDA method, the problems should be identified first. Evaluating the problem in question will help to obtain more accurate results.

To perform sustainability measurement, a great number of parameters and uncertainties must be considered. However, MCDA is found to be an adequate method for sustainability performance assessment as it facilitates the dialogue between scientists and stakeholders. The MCDA provides options at different levels, for example, from product perspective to a policy one by taking into account one or more sustainable development dimensions. MCDA assessment usually considers the economic, environmental and social aspects, depending on the nature of subject under analysis. Hence, it allows comparing the various set of indicators and solving conflicts between these indicators as well.

3.3.6. Barometer of Sustainability (BS)

It is a sustainability measurement model developed by the International Union for Conservation of Nature (IUCN) and the International Development Research Centre (IDRC) [66]. It is used for assessing and communicating societies about the interaction between humans and the ecosystem. The tool provides an overview of human and ecosystem wellbeing and then combines the indicators to provide the results visually for further discussion and analysis. Each indicator is treated separately and then combined independently for analyzing the human-ecosystem interactions. To prevent high score of human factors from offsetting a lower score for ecosystem and vice versa, the lower axis is calibrated so that it overrides the other axis. This method shows the equal importance of both human and ecosystem wellbeing and that there is a need to improve and maintain sustainable development. The tool measures both human and ecosystem on a performance scale without submerging one in the other. For instance, the framework combines various sets of environmental and social indicators using a five band scales good or sustainable on one end and at the other end, bad or unsustainable.

According to the dimensions of the Barometer, there is still the problem of consistent data that are made available. One important point is the conversion of indicator value to Barometer scale. The score is assigned for each indicator by means of linear interpolation technique. The final result is displayed using the same general scale thus enabling the combination of indicators.

3.3.7. Sustainability Assessment by Fuzzy Evaluation (SAFE)

The Sustainability Assessment by Fuzzy Evaluation (SAFE) was developed in 2001 [82]. The model uses the fuzzy inference techniques for measuring sustainable development. The use of fuzzy logic in sustainability assessment is ideal since sustainable development indicators cannot be measured numerically. The SAFE tool comprises of two primary components, namely, the ecological sustainability which consists of air, land, water, and biodiversity and human sustainability which have policy, wealth, knowledge, and health as secondary components. Finally, the tertiary components consist of a set of basic indicators which are created using the Pressure-State-Response framework. The model uses various knowledge bases at different level to represent the indicators and components of sustainability. The end result is the overall sustainability with a numerical value which determines whether the system is sustainable or unsustainable. The model can support vast amount of indicators and it can be easily integrated into it.

The fuzzy approach adopted in this model appears to adequately address sustainability issues. The methods used are also structured in a way that all the important requirements are considered such as data collection, defining the indicators and using fuzzy operators. However, the model does not demonstrate any techniques on how the selection process for indicators is done. Since it deals with an excessive number of indicators, the results may have considerable impact on the area under study. Using larger set of indicators may not lead to unexpected benefits. Potential clutter can arise while dealing with complex indicator sets [83].

3.4. Sustainability Assessment in SIDS

Sustainability assessment is meant to focus on initiatives by which sustainability is evaluated [84]. It is stated that at an early stage of the assessment process, most objectives set for the sustainability assessment should be tested to limit anomalies that may arise later [85]. The objective of sustainability performance measurement practice is to demonstrate how far it can achieve sustainable results if different practitioners have different structures of what the results should be. The assessment must be able to deliver net benefits that will contribute to countries in a positive way. There are many tools which focus on specific sustainability dimension in order to gain advantage of their capabilities and other quality [86]. However, there are very few techniques that address overall sustainabil-

ity. Some comparisons among existing techniques have led to the proliferation of other assessment techniques.

Many research papers were collected from different sources in order to get an overview of existing techniques for sustainability assessment. These measurement techniques work differently with respect to the area of research. However, seven measurement tools have been selected for in-depth analysis as they are applied in sustainability performance assessment at country level. They were also developed to address the three sustainability dimensions and provided an overall measure of sustainability progress. In order to distinguish the limited conditions of sustainability, it is important to identify the different processes and factors which are affecting the environmental, economic, and social systems. The different sustainability measurement techniques use the most appropriate indicators to address sustainability issues at country level. The differences among these techniques are the way sustainability dimensions are categorized, the subject group to be measured and the justification of indicators as well as their aggregation.

To understand the sustainable development processes, the characteristics of the system under analysis should be well-defined. The available economic, environmental and social resources are obviously unsustainable. These problems seem to be complex and hard to manage. They are complex due to multiple causalities, cover various fields and as a result the absenteeism of ready-made solutions [87]. To eliminate the complexity in sustainability assessment, some researchers make use of artificial intelligence techniques. These techniques have the capacity to deal with uncertainty, provide constructive results and work with non-existing data. AI tools are now being applied in the sustainability field. As existing tools do not meet all sustainability issues, AI is found to suit appropriately in this emerging field [88].

As reality changes, many environmental, social, and economic aspects are mostly affected for SIDS. Small Islands share mostly the same characteristics as developing countries but they face challenges and constraints which require an urgent attention. Some of the major constraints SIDS normally face are lack of innovative technological materials and financial constraints. These have a great impact on some key areas such as coastal zones, agriculture, and water resources. It is quite difficult to understand the development level of small island states due to lack of data. In this perspective, there is an urgent need to assess sustainability and identify which key areas need more attention. Due to its capability of mimicking human reasoning, AI technique can address such issues and provide a clear picture for the future [89].

The different tools are analyzed using some criteria as shown in Table 3. The results can help to determine their usefulness of dealing with uncertainty and vagueness.

Table 3. Characteristics of Assessment tools.

Assessment Tools	Robustness	General Applicability	Rapid Assessment	Comprehensive View of Sustainability
Sustainable Society Index	O^r	S	S	S
National Sustainable Development Index	O^r	S	S	S *
System Dynamics	S *	O^r	S *	S
Multi Criteria Decision Analysis	S *	S	O^r	S
Barometer of Sustainability	O^r	S *	S	O^r
Sustainability Assessment by Fuzzy Evaluation	S *	S *	O^r	S
Adaptive Neuro-Fuzzy Inference System	S *	S *	O^r	S

S = satisfied; * = depend on procedures for adoption; O^r = satisfied with some restrictions.

For each assessment tool, the different criteria are examined for their objectives regarding sustainability performance assessment. Most of these tools are found to satisfy the evaluation criteria. However, there is no appropriate tool that fulfil all the criteria that can support sustainability assessment at country level. The Sustainable Society Index can be used for country sustainability assessment but published data is collected from public sources which are doubtful in terms reliability [27]. This can have adverse effects on the final results accuracy and hence affects the robustness of the model. The National Sustainable Development Index has very limited indicator sets which make the assessment become less accurate and reliable for country assessment. This issue can be prevented by considering more indicators for each individual sustainability dimension. If the indicators are kept small, data collection and measurement speed increase. System dynamics is found to be a reliable model but its application in sustainable development makes it a powerful tool. However, this tool is adapted to changes in the system under study and does not use fixed indicators. If the data is limited, this affects the completeness of the model which can impact on the relationship between variables [45]. Its extensive applications in various fields and sectors make the criteria general applicability differs in some situations and subject areas under study. Multi Criteria Decision Analysis, Sustainability Assessment by Fuzzy Evaluation, and Adaptive Neuro-Fuzzy Inference System are tools that do not fully satisfy the criteria rapid assessment since they deal with large indicator sets. However, they are robust depending on how they are implemented and also provide reliable and accurate results. Since the number of indicators vary in barometer of sustainability, the methodological approaches remain flexible. This can affect the robustness of the model. It does not fulfil the criteria comprehensive view of sustainability as the number of indicators can be limited in some of the sustainability dimensions.

4. Discussion

4.1. Sustainability Dimensions

Many countries have developed sustainable development strategies which reflect the integrated sustainability spheres specificities of the countries but there are countries which are paying more attention on individual dimensions rather than the three spheres. For example, Denmark focuses more on integrating environment considerations in various sectors while Australia concentrates mostly on environmental strategies for its coastal zones. Japan is focusing mostly on the environment and in its strategy it considers global warming, recycling of materials, and biodiversity. The social dimension is the most neglected in national strategies as less attention is being paid on human development [90]. Social goals and objectives are always treated individually but are rarely combined with the environmental and economic dimensions. Some of the tools focus on the living conditions of the citizens while others concentrate more on poverty, education and criminality rate.

The overall sustainability of a country is highly dependent on time period objectives should be achieved. Countries plan their strategies for a short period of five years, others for 10 years, and some long-term timeframes can last up to 25 years. A longer timeframe allows to review the policies to reduce public expenditure, optimize the resources while preserving the environmental conditions. In practice, it is very difficult to balance the three sustainability spheres while formulating national strategies. The complexities further increases for SIDS since they face numerous challenges. Despite their low contributions to climate change they are highly vulnerable to the impacts of climate change.

4.2. Sustainability Assessment Strategies at Country Level

Having considered all the important aspects of sustainable development, it is quite imperative to understand every single process as it does have many challenges compared to our way of living. Sustainable development is a valid concept for both developing and developed countries. Some developed countries have undergone many changes over time but it does not imply that they are sustainable because the main objectives of these countries were to get rid of societal issues such as waste and environmental management

and social imbalances. However, these sustainability issues that occur in various systems such as social inequality or environmental change demonstrate some challenges which are unsystematic [91]. In order to address these problem areas, it is important to involve stakeholders who can work in ambiguous and complex contexts so as to implement sustainable actions and maintain them in the long-run. Sustainability issues are quite complex and difficult to tackle and these types of problems need comprehensive and various solutions which come from different people. In addition, leadership should be understood as a process that impacts on all the subordinates where the expected results are achieved [92].

Despite the efforts made by international researchers to measure sustainability, it still remains an important challenge to provide efficient tools [93]. Sustainability assessment has had significant impact on the short term decisions which show better results rather than long term decisions [94]. This is because long term decisions have very limited interest since it needs constant management and planning.

The most desired point of most governments is to identify and assess changes in the economic, environmental, and social conditions of their respective countries. If not properly measured, it will be difficult to improve the sustainability performance of a country. To achieve sustainability, policy-makers must obtain information in a timely manner as this will indicate whether the system is becoming more sustainable or not and specific information about the characteristics of the system will help to identify the need for improvement. The ongoing changes between human activities and the natural environment have evolved with technological advancement and economic growth. The pressure human activities is exerting on the earth is significant and can be disastrous for human welfare. It is important to track and assess progress so as to anticipate new requirements to address complex issues. This can help to increase awareness of sustainability and manage the major challenges countries are facing.

4.3. Assessment Methods

Sustainability assessment is just a way of showing how decisions are made towards sustainability performance [95]. Its aim is to deliver net benefits that will contribute positively to sustainability. Sustainability assessment techniques are mainly designed to address sustainability issues with main objectives to demonstrate how far they can achieve sustainable results if practitioners have different structures of what the results are going to be.

Sustainability assessment at country level is based on the level of sustainability of the country in terms of problems facing in the three dimensions [64]. These sustainability issues concern the activities people are doing which are impacting on the ecosystem [96]. With the absence of a truly integrative approach, sustainability assessment does not really help the decision-makers and the stakeholders. Efforts and programs towards measuring sustainability are becoming significant research topics since they impact on various fields such as economic, environmental, and social. The severity and interlinkages of the global crises pose an unprecedented challenge. It is observed that very few techniques address the overall sustainability. Since it is complex in nature and difficult to measure, the use of appropriate techniques to bring together an established assessment technique is fundamental. The way progress is being assessed represents a key level for undertaking the root causes of sustainability [97].

There are some major challenges that some countries are facing while considering sustainable development in their agendas. Most of the developed countries express regrets for not having used consultants at a much earlier stage in order to protect the world ecosystem. However, some developing countries are still contributing greatly to a rise in sustainable development although the difficult situations they are actually facing [98]. Others countries, more specifically SIDS are totally dependent on what others are doing. In some cases, experts become an option for these small island states in terms of sharing of knowledge.

Developed and developing countries are now considering sustainable development as a major priority. However, less attention is paid on small island states. In this paper, the existing tools show significant results but do not fulfil the criteria to conduct assessment for SIDS. There are many differences among existing tools concerning the ease of use, their assessment procedure and the availability of data. The indicators are too general and large for implementing in SIDS. A small number of indicators can reduce the assessment time. Simply speaking, the data set for SIDS are different due to their unique characteristics that contribute to their vulnerabilities. Therefore, they are highly disadvantaged compared to larger developing countries in terms of economic and development performance. With their small domestic markets, they depend heavily on external markets and natural resources.

5. Conclusions

This paper provides a review of existing sustainability tools which are mainly applied at country level. Although there are various sustainability performance measurement techniques, only few of them integrate the environmental, economic, and social dimensions. The selected tools consider the three sustainability spheres where most of them were widely used in various sustainability assessment projects. There are other assessment tools which exist but their objectives are limited by either the sustainability dimensions they are considering or the areas under which studies were conducted. As we stressed on tools that can be applied globally, these approaches give the opportunities to explore the emerging technologies in sustainable development thus provide a broader notion in sustainability assessment. We believe that these approaches are among most of the promising tools for sustainability performance measurement. By simply comparing and analyzing those tools, we have noticed that the indicators used, were more specifically selected for developed countries and some developing countries. Since SIDS are smaller in size with its unique biodiversity, culture, coastal environment, and tourism assets among others, it is important to consider these aspects for SIDS. Some of the approaches in the evaluation matrix do not fully satisfy some criteria due to variations in the indicators in terms of scales and unit of measurement. This can be time consuming for conducting the assessment. Although SIDS share the same sustainable development challenges with developing countries, the situation is not similar for indicator sets which are collected on different scales. The problem of not analyzing and considering sustainability issues in small islands may decrease the assessment accuracy to some extent. It is important to find a compromise between these complex issues. As a starting point for a future research, it is vital to be engaged in reviewing the methodological processes. Due to lack of assessment tools in this area, it is important to conduct extensive research in SIDS. Accordingly, a comprehensive measurement technique based on the integrated sustainability spheres is needed and adaptable for SIDS.

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